

DIRECT METHANOL FUEL CELL

Field of the Invention

The invention is directed to a direct methanol fuel cell (DMFC).

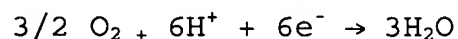
Background of the Invention

The direct methanol fuel cell (DMFC) catalytically oxidizes methanol to generate electricity. The DMFC differs from PEM (proton exchange membrane) or solid polymer fuel cells, which use hydrogen gas for generating electricity. One major advantage of the DMFC over the PEM fuel cell is its ability to use methanol, a relatively inexpensive and easily handled material when compared to hydrogen gas. One major disadvantage of the DMFC, when compared to the PEM fuel cell, is methanol crossover. Methanol crossover occurs when methanol from the anode crosses to the cathode. This causes the loss of efficiency of the cell. Nevertheless, the DMFC appears to be a viable portable power source for devices such as cellular or mobile telephones, and handheld or laptop computers. "Types of Fuel Cells," Fuel Cells 2000, www.fuelcells.org; Thomas, et al, "Fuel Cells-Green Power," Los Alamos National Laboratory, LA-VR-99-3231.

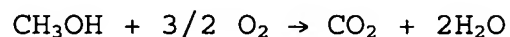
The DMFC is an electrochemical device. The anodic catalyzed reaction is:



The cathodic catalyzed reaction is:



The overall cell reaction is:



These cells operate at efficiencies of about 40% at temperatures of 50-100°C, the efficiencies will increase at higher operating temperatures. Fuel Cells 2000, *Ibid*; Thomas, *Ibid*.

As with any chemical reaction, reactants, products, and unwanted products (by-products) become mixed as the reaction proceeds, and separation of these materials is an engineering challenge. So, at the anode, methanol, water, and carbon dioxide will be mixed together. One must be careful that excess methanol not accumulate at the anode because it will crossover the proton conducting membrane (PCM) and decrease the cell's efficiency. Water is good for the PCM, which needs water to maintain its proton conductivity, but if water accumulates, it can prevent methanol from reaching the catalyst, or it can be recycled back into fuel mixture where it can dilute the fuel. Both can decrease the efficiency of the cell. Carbon dioxide (or CO_xs) must be removed

to allow room for the fuel at the anode. Otherwise, cell efficiency can suffer.

Likewise, at the cathode, oxygen typically from air, must reach the cathode and water must be removed. If oxygen cannot reach the cathode, efficiency drops because the cathode half cell reaction is impeded. If water, which can be used to moisten the PCM, is allowed to accumulate, it will prevent oxygen from reaching the cathode.

One challenge related to the foregoing is managing the reactant/product issues without greatly increasing the size or weight of the DMFC. DMFC is targeted, in part, at a portable power source for cellular or mobile telephones and handheld or laptop computers.

In WO 02/45196 A2, a DMFC is disclosed. Referring to Figure 3, the DMFC 40 has proton conducting membrane (PCM) 80 with CO₂ conducting elements 52. On the anode side 41, there is a conducting plate 23 that has a flow field 25, a gas diffusion layer 44, and an anodic catalyst 42. On the cathode side 31, there is a conducting plate 33 with a flow field 35, a gas diffusion layer 48, and a cathode catalyst 46. The catalyst, anode or cathode, is applied to either a surface of the PCM 80 or to the gas diffusion

layers 44, 48. The respective flow fields are in communication with their respective gas diffusion layers and the combined action of these flow fields and diffusion layers is intended to ensure the even distribution of reactants to the catalyst and the efficient removal of unwanted products, by-products, and unreacted reactants for the reaction. The gas diffusion layers are made of carbon fiber paper and/or carbon fiber cloth and may be "wet-proofed" with PTFE polymer. Note that the gas diffusion layer, catalyst, and PCM are in close contact to promote electrons or protons conductivity.

On the anode side, fuel (methanol, methanol/water in either liquid or vapor form) is introduced at one end of the flow field 25, and by products (water, CO₂, and un-reacted fuel) are removed at other end of the flow field 25. CO₂ produced at the anode is intended to cross the PCM 80 via CO₂ conductors 52. Water produced at the anode is not meant to remain in the gas diffusion layer 42 as is apparent from the use of the PTFE. On the cathode side, air (the source of O₂) is introduced at one end of flow field 35, and water, unreacted air, and CO₂ are removed at the other end of flow field 35. Water produced at the cathode is not intended to remain in the gas diffusion layer 48 as is apparent from the use of the PTFE.

In U.S. Patent Application Publication 2002/619253 A1, another DMFC is disclosed. This DMFC is similar to the foregoing DMFC, except the carbon paper or carbon cloth gas diffusion layers are replaced with a porous metal layer. See paragraphs [0022-0024].

Accordingly, there is a need to improve reactant, product, and by-product management at both the anode and cathode of DMFC while not significantly increasing the size or weight of the DMFC.

Summary of the Invention

A direct methanol fuel cell has a proton conducting membrane (PCM), a catalyst in contact with the PCM, a gas diffusion layer in contact with the catalyst, and a conducting plate in contact with the gas diffusion membrane. The gas diffusion layer comprises a microporous membrane.

Description of the Drawings

For the purpose of illustrating the invention, there is shown in the drawings a form that is presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

Figure 1 is a schematic illustration of a direct methanol fuel cell (DMFC) made according to the present invention.

Figure 2 is a schematic illustration of a plurality of DMFC's connected in series.

Figure 3 is a schematic illustration of a plurality of DMFC's connected in parallel.

Description of the Invention

Referring to the drawings, wherein like elements have like numerals, there is shown in Figure 1 a direct methanol fuel cell system 10.

DMFC system 10 includes a DMFC 12, a fuel source 14, and an electrical circuit 16. DMFC may include one or more DMFC. Fuel source 14 is a storage vessel that contains the fuel, methanol, or a mixture of methanol and water. Electrical circuit 16 includes a switch 18 and a load 20. Load 20 may be any device that requires electricity, such as a cellular or mobile telephone, or a handheld or laptop computer, or the like. Fuel is supplied to DMFC 12 via line 22 from source 14 and is returned to source 14 via line 24 from DMFC 12. Air is supplied to DMFC 12 via line 26 and vented from DMFC 12 via line 28.

DMFC 12 includes a membrane electrode assembly (MEA) 30 preferably sandwiched between a pair of collection plates 32, 34. Collection plates are electrically conductive and are coupled to electrical circuit 16. Collection plate 32 includes a fuel distribution channel 36. One end of channel 36 is in fluid communication with line 22 and the other end of channel 36 is in fluid communication with line 24. Collection plate 34 includes an oxidant distribution channel 38. One end of channel 36 is in fluid communication with line 26 and the other end is in fluid communication with line 38. The geometry of channels 36 and 38 is such that fuel or oxidant is even distributed to the catalysts of the DMFC 12.

MEA 30 includes a proton conducting membrane (PCM) 40 with an anode catalyst 42 on one side thereof and a cathode catalyst 44 on the other side thereof and all sandwiched between gas diffusion layers 46 and 48. PCM 40 is conventional, for example NAFION® (perfluorosulfonic substituted polytetrafluorethylene (PTFE)) from DuPont, Wilmington, DE or the materials set forth in WO 02/45196A2, incorporated herein by reference which include NAFION®-TEFLON®-phosphotungstic acid (NPTA), NAFION®-zirconium hydrogen phosphate (NZHP), polyetheretherketone, polybenzimidazole, polyvinylidene fluoride (PVDF). Anode catalyst 42 may be adhered to a face of PCM 40 or adhered to the fiber surfaces of a carbon fiber mat or cloth.

Likewise, cathode catalyst 44 may be adhered to the other face of PCM 40 or adhered to fiber surfaces of a carbon fiber mat or cloth. The anode and cathode catalyst are conventional and the methods of adhering same are also conventional.

The gas diffusion layers 46 and 48 may comprise a microporous membrane or a laminate of a microporous membrane and carbon fiber substrate. The microporous membrane may take on several different forms, the ultimate form being dependent upon the desired function of the membrane. Functions of the membrane will be dependent upon whether it is located on the fuel tank, or the anode and or the cathode. Functions for membranes at the fuel tank include: allowing the fuel to directionally flow to the anode and preventing the flow back of other anode components, reactants and reaction products. Functions for membranes at the anode include: allowing the fuel directionally flow to the catalyst; preventing accumulation of water at the catalyst; facilitating removal of gaseous reaction products from the electrode; maintaining adequate water level by preventing the back flow of the anode liquid to the fuel tank; helping to prevent accumulation of MeOH at the catalyst thereby reducing the chance for methanol crossover. Functions for membranes at the cathode include: allowing directional flow of the oxygen or air to the cathode catalyst for electrochemical reaction, and preventing the water loss of the fuel cell system.

Membranes suitable to address these functions include microporous or nonporous membranes, skinned membranes, symmetric or asymmetric membranes, single or multi-layered membranes, and combinations thereof. Such membranes are known, see for example, Kesting, R., *Synthetic Polymeric Membranes*, 2nd Edition, John Wiley & Sons, New York, NY (1985), incorporated herein by reference. Such membranes are made of thermoplastic materials, such as polyolefins (polyethylene, polypropylene, polybutylene, polymethyl penetene and the like), polyamides (nylons), polyesters (PET, PBT and the like). The membranes may be made by the Celgard® process or by a TIPS (thermally induced phase separation) process or a wet (solvent extraction) process. Additionally, the membranes may have functional coatings, for example, hydrophobic or hydrophobic coatings. Such coatings are conventional. The membranes may also be combined with perm-selective gels or polymers that preferably pass one or more of the reactants, products, or by-products. Such perm-selective gels or polymers are conventional. Such a perm-selective material could coat one or more sides of the membrane or be sandwiched between membranes.

As an example of the foregoing, one may use an asymmetric membrane (pores with decreasing diameters from one surface of the membranes to the other) that is coated with a hydrophobic material

on the surface with the narrow pores. This membrane is preferably made from polymethylpentene (PMP). This membrane, which could be used at either the anode or cathode, would be placed in the MEA with the coated face toward the PCM. Thereby, water that is a reactant at the anode and a product at the cathode would be retained around the PCM are available to moisten the PCM so that its proton conductivity is maintained.

Figures 2 and 3 illustrate further embodiments of the invention. In these embodiments, a plurality of DMFC's are joined together to form a stack 50. In Figure 2, the DMFC's 12 are joined in series. In Figure 3, the DMFC's 12 are joined in parallel.

The present invention may be embodied in other forms without departing from the spirit and the essential attributes thereof, and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification, as indicated the scope of the invention.